NAVAL EXPLOSIVE SAFETY IMPROVEMENT PROGRAM
(MILESTONE II-1)
PLANS AND PROGRAMS

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The Naval Explosives Safety Improvement Program (NESIP), Milestone II-1, has as its objective the examination of Naval munitions in the quantities and scenarios experienced on Naval waterfronts, to determine fragment and blast hazard ranges. This paper will review the organization of the program, discuss several of its major on-going testing programs, review some of its many past accomplishements, and discuss its relationship with the Navy's Weapon System Explosive Safety Review Board. Specifically, the paper will review findings and testing concerning hazard ranges and sympathetic detonation of bombs and torpedoes in the open and torpedoes in certain classes of ships. It will discuss analytic studies of several Navy Weapon Systems including the Penguin Missile System and the Destructor MK 14 MOD 0. In addition it will present previously unpublished fragment velocity data taken from the NESIP data base.

The Chief of Naval Operations initiated the Naval Explosives Safety Improvement Program (NESIP). In 1974, the program was established for the purpose of assessing the Navy's compliance with DDESB standards on explosive handling waivers and explosive safety problems in general. A collateral objective was to develop military construction programs to eliminate such problem areas where possible.

The scope of the entire current NESIP effort is shown in a breakdown of tasks by Milestone number in Table 1. This paper will deal solely with Milestone II-1, "Prosecute Naval Explosive Safety Test (NEST) Program."

This Milestone (II-1) has as its objective the examination of Naval munitions, in the small quantities handled on Naval waterfronts, and in the several explosive handling scenarios which are experienced, to determine fragment and blast hazard ranges. The ultimate goal is the reduction of explosive-safety quantity-distance (ESQD) arcs which must be applied to small quantity handling evolutions. These define the basic scope of the program. The program deals with handling scenarios: transportation, loading, topping off, etc. It is also generally limited to small quantities of munitions. Small in the context of transportation and handling scenarios generally means no more than 1500 pounds Net Explosive Weight (NEW). (Note: The handling of small quantities of munitions excludes major facilities such as the Naval Weapon Station, Yorktown; it does include facilities such as those located at Charleston and San Diego).

In the past, the Navy has operated under Explosive Safety Quantity-Distance (ESQD) waivers at most of its tidewater port complexes during explosive handling operations which are necessary to maintain fleet operational readiness requirements. Much of the problem that brought about the imposition of these waivers in the first place resulted from the application of Department of Defense Explosive Safety Board (DDESB) general standards to specific Navy operations at these ports -- operations that are less severe and more limited in scope than those to which the DDESB standards are generally applied. These DDESB standards, as interpreted by the Navy are an ESQD arc of "... 670 feet for 100 pounds NEW (New Explosive Weight) or less. For 101 to 30,000 pounds NEW, the minimum distance will be 1250 feet unless it can be shown that fragments and debris from structural elements of the facility or process equipment will not present a hazard beyond the distance specified..."[1]

The Navy recognizes the necessity of maintaining adequate safety standards. Moreover, it accepts the DDESB criteria for acceptable hazards. These criteria are:

1. Less than 1 psi blast overpressure, and

2. A hazardous fragment flux evaluated for the ground surface area of less than one hazardous fragment per 600 ft^2. A fragment is considered hazardous if it has an impact energy of 58 lb-ft or greater.

It is recognized that the DDESB's policy is to make changes in the ESQD tables if it is demonstrated that the new arcs for each specific scenario are realistic and do not compromise safety.

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[1] Ammunition and Explosives Ashore: Safety Regulations for Handling, Storing, Production, Renovation, and Shipping, NAVSEA OP5, Vol. 1, Rev 10, 1 Nov 1981.

In essence then, each Naval munition or weapon system must be examined to answer the following questions:

1. Given the detonation of one round, what are its effects on any surrounding rounds? Will the surrounding ordnance sympathetically detonate? What is the Maximum Credible Event (MCE)?

2. For the MCE, and applying the DDESB standards given above, what is an appropriate ESQD arc?

The approach has been two-fold -- analytical and experimental. Predictions are made using the analytical techniques developed for this program. These predictions are then verified experimentally. When the theory is inadequate, it is developed/refined and experimental tests are conducted to determine relationships from the data. The analytical techniques form the NESIP Technology Base, which was described by Porzel[2] at the 1980 DDESB seminar. Currently, approximately 60% of the effort is analytical and 40% experimental. At the onset of the program, all analyses/predictions were verified experimentally (100% testing). As the results of these analyses and predictions were compared with the experimental data, it became obvious that less testing would be required. In every case in which differences occur between the Technology Base predictions and the experimental results, the Technology Base has been more conservative (i.e., required a larger ESQD arc). Because of the development of the Technology Base, answers to ESQD problems can now be obtained much more easily and reliably. The technology is now well-developed and operable. It is used for analysis and test guidance. Together -- analysis and tests -- they are giving the answers to the questions asked: "What are the ESQD values for specific Navy Scenarios?"

Because of the development of the Technology Base and its successful application, the CNO introduced[3,4] in 1979 a mandatory requirement that all programs for the development and introduction of new weaponry into the fleet include analyses developed by the NESIP and/or verifying tests (as recommended by NESIP) to insure the timely availability of hazard information for review by the Weapon Systems Explosives Safety Review Board (WSESRB). The CNO specifically tasked Milestone II-1 of the NESIP to assess the sympathetic detonation characteristics and the explosion hazard effects of weapon systems that are presented to the WSESRB. These efforts are to be funded by the weapon systems project managers. If the weaponry is found to be unacceptably hazardous, then the NESIP Milestone II-1 is to fund an effort to reduce the hazard to an acceptable level.

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[2] Porzel, F. B., "Technology Base of the Navy Explosives Safety Improvement Program," Minutes of the Nineteenth Explosives Safety Seminar, Los Angeles, CA, 11 September 1980.

[3] CNO ltr Ser 411F/318499 of 5 Feb 1979.

[4] NAVSEA ltr 04H3/EAD Ser 363 of 22 May 1979.

In 1978, Petes[5] presented an outline of this milestone and certain of its accomplishments. Table 2 presents a summary of the weapons/scenarios which have been examined (analyzed and/or tested) since the program inception. Many of these findings have been reported previously in some detail[2,6-15] in the open literature.

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[5]Petes, J., "The Navy's Explosive Safety Improvement Program for Pier Side Munitions Operations," Minutes of the Eighteenth Explosives Safety Seminar, San Antonio, TX, 12-14 September 1978.

[6]Porzel, F. B., "Design of Lightweight Shields Against Blast and Fragments," Minutes of the 17th Explosives Safety Seminar, DOD Explosives Safety Board, Denver, CO, 1976.

[7]Porzel, F. B., "A Model and Methods for Control of Sympathetic Detonation," Minutes of the Eighteenth Explosives Safety Seminar, DOD Explosives Safety Board, San Antonio, TX, Sep 1978.

[8]Martin, G. H., "The Explosives Hazard Presented by the Torpedo Magazine of a Guided Missile Frigate (FFG Series) During Pier-side Topping-Off Operations," 19th DDESB Seminar, Los Angeles, CA, Sep 1980.

[9]Connor, J. G., "Hazards from Accidental Explosions in Submarine Tender Workshops," Minutes of the Nineteenth Explosives Safety Seminar, DOD Explosives Safety Board, Sep 1980.

[10]Ward, J. M., "Simulated Tomahawk Missile Handling Arc Test Results," Minutes of the Eighteenth Explosives Safety Seminar, DOD Explosives Safety Board, San Antonio, TX, Sep 1978.

[11]Ward, J. M., "Blast/Fragment Hazards Associated with Accidental Explosion of a MK 82 Bomb Pallet," Minutes of the Nineteenth Explosives Safety Seminar, DOD Explosives Safety Board, Sep 1980.

[12]Porzel, F. B. and Ward, J. M., "Safety Analyses of the Machrihanish Magazine," NSWC TR 79-359, Naval Surface Weapons Center, White Oak Laboratory, 1979.

[13]Porzel, F. B., "Propagation of Explosions in the Machrihanish Magazine: Vulnerability of Thin-Cased Munitions to Massive Debris," Vol. 5, Seventh Quadripartite Ammunition Conference, London, England, Oct 1979.

[14]Swisdak, M., Jr., "Determination of the Safe Handling Arcs Around Nuclear Attack Submarine," Minutes of the Nineteenth Explosives Safety Seminar, DOD Explosives Safety Board, Los Angeles, CA, Sep 1980.

[15]Connor, J. G., "Shields for Decelerating Munitions Fragments," Minutes of the Eighteenth Explosives Safety Seminar, DOD Explosives Safety Board, San Antonio, TX, Sep 1978.

The remainder of this paper will review some of these findings. In addition, some of the previously unreported results will be presented. Other papers at this seminar will discuss still other facets of the work. Finally, several on-going experimental programs will be briefly discussed.

A major emphasis in the program has been the ESQD arcs required for torpedoes. The work was begun with obsolete MK 16's and is currently continuing with the newest MK 48's. It was discovered that the torpedo warhead fragments are not the culprits, since the warheads are relatively thin-skinned. The fragmentation hazard range is driven, rather, by parts of the truck or other vehicles used to transport the warheads. The ESQD arc for two torpedoes in the open is within 500 feet. When the torpedoes are placed on a truck, however, the ESQD arc extends well beyond 500 feet. This is because the truck becomes a major source of large secondary fragments. Through the use of a simple shield the warhead detonation was decoupled from the truck, reducing the hazard ranges to an acceptable level. This simple shield design is shown in Figure 1.[6]

Another part of the torpedo effort has been work done to reduce the MCE. At the spacings generally encountered in torpedo magazines aboard ship, if one torpedo detonates, the remainder should sympathetically detonate. The simple expedient of nose-to-tail stowage (as opposed to nose-to-nose stowage), as shown in Figure 2, reduces the liklihood of sympathetic detonation. If, in addition to nose-to-tail stowage, inhibitor plates are placed between rounds, the MCE can be limited to one warhead. (Note: sympathetic detonation is inhibited; lower order reactions such as burning are not automatically excluded). This has been demonstrated previously for MK 16 and MK 46 torpedo warheads. A recently completed experimental program has demonstrated the feasibility of this concept for MK 48 torpedo warheads.

It should be noted that the NESIP simply recommends methods of reducing sympathetic detonation and the ESQD arcs. The actual design and retro fit of these concepts are engineering problems that are being handled by the various ship engineering offices.

As part of these same studies, it was found that the OTTO Fuel does not detonate for the projected threat scenarios and thus does not contribute to the MCE.

Another effort[11] has involved the ESQD arcs produced by the detonation of pallet loads of MK 80 series bombs. The program has shown that if one H-6 filled bomb in a standard pallet configuration detonates, the remainder of the bombs within the pallet will also detonate within 300 microseconds. Furthermore, if pallets are stacked one on top of another or side-by-side as closely as possible, and if detonation begins in one pallet, it will spread to the surrounding pallets. Thus the MCE is the number of pallets in close proximity multiplied by the number of bombs in each pallet.

If the MCE is limited to a single pallet (approximately 900 to 1900 pounds NEW for bombs in the MK 80 series) resting on a flat surface in the open, the ESQD arc can be defined for this scenario. Test results indicate that for both MK 82 and MK 83 bombs (and by generalization all bombs in the MK 80 series), the ESQD arc is controlled by airblast and not by fragmentation. Figure 3 is a plot of NESIP generated pressure-distance data for MK 80 bombs (scaled to one

pound at sea level). One psi occurs at a scaled range of 56 ft/lb$^{1/3}$ (approximately 600 feet for pallets of MK 82's and MK 83's and 700 feet for MK 84's). As part of the NESIP procedures, this data was compared with multi-source archival MK 80 data as shown in the next figure (Figure 4). The solid line in this figure is the NESIP Technology Base prediction for H-6 (Equivalent Weight of 1.3) in a steel case (case weight to explosive weight of 1.5). All of the data as well as the prediction are in excellent agreement.

As determined by NESIP tests, the ESQD arc based on fragmentation for single pallets of MK 80 series bombs is within 500 feet (i.e., less than one hazardous fragment per 600 square feet ground surface area). It should be noted that hazardous fragments do travel beyond 500 feet from ground zero. However, there is no physical reason why the ground surface areal density should be anything but a decreasing function with range beyond 500 feet for these naturally fragmenting bombs. This has been investigated in a series of tests conducted at White Sands Missile Range, New Mexico by the Terminal Effects Branch of the Naval Surface Weapons Center. In these tests, pallet loads of bombs were detonated and fragments recovered out to at least a range of 2000 feet. Analyses of these data are continuing.

A study was recently completed of the PENGUIN missile system. This is a Norwegian developed missile utilizing a BULLPUP A warhead as shown in Figure 5. The U. S. Navy plans to configure four missiles on a MK 3 patrol boat, as shown in Figure 6. Analyses indicate that if one warhead detonates, the remaining warheads and all the solid propellant will sympathetically detonate. OP-5[1] and Porzel[2] indicate that for the PENGUIN propellant, a TNT equivalency of 25% is appropriate for determining the MCE. Based on a single missile (warhead plus propellant contribution) the ESQD arc is 300 feet. For a four missile (MK 3) configuration the ESQD arc is 485 feet. Again in this instance, blast determines the arc, not fragmentation.

Because of the questions raised by this and other studies, the NESIP has undertaken a program to determine the TNT equivalency of several standard Navy gun and rocket propellants. The tests will be conducted on several types of propellants (single and double base solid propellants as well as two types of gun propellants). Care is being taken to maintain that all charges are above their critical diameter for detonation, and that the initiation stimulus is more than sufficient to achieve detonation (explosive boosters whose weights are approximately 10% of the propellant weight being tested).

Another recently completed study is that of the Mine Neutralization System Bomblet (DESTRUCTOR MK 14 MOD 0) (Figure 7). This is an underwater bomb designed to be dropped from a submersible. The case is non-metallic, with a nine-pound lead ballast in the nose. Calculations indicate that the weapon in its shipping container will mass detonate when stacked in a side-by-side configuration. The ESQD hazard range is determined solely by airblast; the case and container fragments do not contribute to the range. Up to nine weapons can mass detonate and still meet the desired hazard criteria at 500 feet. The palletized configuration of this weapon has not, as yet, been determined. These results will be used in defining a "pallet load." The lead ballast in the nose of each bomblet constitutes a special fragment hazard, in that it is massive

and may be expelled nearly intact. If the ballast is expelled near an optimum launch angle, it could go up to four miles. Moreover, the ballast would constitute a single fragment or a relatively small number of fragments so that the areal density at 500 feet should not exceed the acceptable hazard criterion.

The NESIP (Milestone II-1) program effort has been an on-going program for about eight years. During this time, it has answered safety/hazard questions for many Navy weapon systems. Moreover, it has produced a broad data base which can be applied not only to safety problems but to vulnerability problems as well. One example of this data base is the answer to the question "What are the initial fragment velocities produced by Navy weapons?" The answer is usually known for fragmenting weapons; however, fragmentation data is usually not of concern to the torpedo designer. Table 3 presents a compendium of NESIP fragment velocity data extracted from the data base.

The results of the entire Milestone II-1 effort can be summarized as follows:

All current Navy weapons and scenarios which have been tested or analyzed thus far are either acceptable hazards near 500 feet or could be made so.

The program is continuing. As indicated above, the emphasis this year has been on problems associated with submarine tenders (ESQD arcs for workshop accidents and sympathetic detonation inhibitors for MK 48 torpedoes) and the TNT equivalency of propellants. Future efforts will continue the propellant equivalency work and begin studies of preformed fragment warheads and LFORM ammunition and ships.

TABLE 1 NESIP PROGRAM

MILESTONE NO.	TASK
	I. OVERSIGHT AND REVIEW OF PROGRAM
I-1	PROVIDE NESIP SUPPORT SERVICES TO OPNAV
I-2	CONDUCT PERIODIC REVIEWS OF NESIP
I-3	CONDUCT AMHAZ REVIEWS
I-4	MAINTAIN WAIVER DATA BANK
I-5	MAINTAIN CAPABILITY FOR EXPLOSIVES SAFETY INSPECTIONS/SURVEYS, ON AN 18-MONTH BASIS, AFLOAT AND ASHORE
I-6	REVIEW ACTIVITY MASTER PLANS FOR EXPLOSIVES SAFETY IMPLICATIONS
I-7	COMBINED WITH ACTION ITEM I-5
I-8	MAINTAIN CURRENT THE STANDARD EXPLOSIVES SAFETY INSPECTION CHECKLIST FOR SHIPBOARD INSPECTIONS
	II. ISSUES WITH DDESB
II-1	PROSECUTE NAVAL EXPLOSIVES SAFETY TEST PROGRAM
II-2	INCORPORATE MAGAZINE IMPROVEMENTS IN LFORM AMMUNITION SPACES IN AMPHIBIOUS WARFARE SHIPS
II-3	CHANGE HOMEPORT OF NORFOLK-BASED AOEs
II-4	PREPARE AND PRESENT ACTIVITY OR REGIONAL MASTER PLANS TO DDESB
II-5	CORRECTION OF DDESB-REPORTED EXPLOSIVES SAFETY DEFICIENCIES
II-6	FORMALIZE NAVY INTERIM EXPLOSIVES SAFETY STANDARDS (OPNAVINST 8023.21A)
II-7	ESTABLISH STANDARD PROGRAM FOR COMPUTING NET EXPLOSIVE WEIGHT (NEW)
	III. OTHER SIGNIFICANT PROBLEM AREAS
III-1	IDENTIFY MILCON PROJECTS FOR INCLUSION IN INVESTMENT PROGRAM 55 (DIRECTED EXPLOSIVES SAFETY INVESTMENT PROGRAM)
III-2	PROCESS WAIVER REQUESTS/UPDATES/VALIDATIONS
III-3	ANALYZE ABSLA'S TO MINIMIZE WAIVER NEEDS
III-4	NO ITEM ASSIGNED
III-5	CANCELLED
III-6	CLOSURE OF PORT CHICAGO HIGHWAY
III-7	SMALL ARMS TARGET RANGES: DESIGN, CERTIFICATION, WAIVERS
III-8	PROSECUTE THE NAVY EXPLOSIVES SAFETY FACILITIES PROJECT
	IV. POLICY GUIDANCE MATTERS
IV-1	MAINTAIN CURRENT THE NAVY EXPLOSIVES SAFETY POLICY GUIDANCE DOCUMENTS (e.g., OPNAVINSTS 8023.2/.13/.20/.21, 8020.8, 5101.1, ETC.)
IV-2	INSURE CURRENCY OF EXPLOSIVES ACCIDENT AND INCIDENT (EXPLOSIVES MISHAP) REPORTING DIRECTIVE AND RESPONSIVENESS THERETO AT COMMAND LEVELS

TABLE 2 WEAPONS AND SCENARIOS TESTED/ANALYZED

TORPEDOES	PROJECTILES	MISSILES	BOMBS
MK 16	5"/54 (A-3)	TOMAHAWK	MK 82
MK 46	5"/54 (EXP. D)	HARPOON	MK 83
MK 48	5"/54 HIFRAG	PENGUIN	
	76 mm	2.75" FFAR	
	5" GUIDED	TOW	
		SPARROW	

ESQD FOR SHIPS

SSN 688 CLASS*
SSN & SSBN (ALL CLASSES)*
MK 3 PATROL BOAT*
FFG-7**

[illegible]ICE/NEW MAGAZINES

FFG-7
AS-18*
MACHRIHANISH

SHIP VULNERABILITY TO PIER-SIDE ACCIDENTS

DDG-2

SYMPATHETIC DETONATION INHIBITOR DESIGN

MK 16 TORPEDO
MK 46 TORPEDO
5"/54 (A-3) PROJECTILE
MK 48 TORPEDO

* INCLUDES NESTED SHIPS
** WORK IN PROGRESS

TABLE 3 NESIP FRAGMENT VELOCITIES

MUNITION	EXPLOSIVE	CASE MATERIAL	CASE THICKNESS (IN.)	AVERAGE VELOCITY (FT/S)**	INITIAL VELOCITY (FT/S)***
MK 16 TORPEDO	HBX-1	BRONZE	0.125	9100	—*
MK 46 TORPEDO	PBXN-103	ALUMINUM	0.250	8200	—*
MK 48 TORPEDO	PBXN-103	ALUMINUM	0.250	9300	–
5"/54	A-3	STEEL	0.66	4360	4630
76 mm (BARE)	A-3	STEEL	0.66	3530	3680
76 mm (CANNISTERED)	A-3	STEEL	0.66	3070	3160
TOMAHAWK (BULLPUP WARHEAD)- IN SHIPPING CONTAINER	H6/ PICRATOL	STEEL	0.78	6000	7300
MK 82 (SINGLE BOMB)	H-6	STEEL	0.50	6300	8000
MK 82 (PALLET)	H-6	STEEL	0.50	9300	11,500
MK 83 (SINGLE BOMB)	H-6	STEEL	0.50	7300	8500
MK 83 (PALLET)	H-6	STEEL	0.50	10,200	12,700

* EXTRAPOLATIONS ARE NOT INCLUDED FOR THINLY-CASED MUNITIONS

** AVERAGE VELOCITIES ARE BASED ON DIFFERENT MEASURED DISTANCES FOR EACH MUNITION

*** BASED ON EXPONENTIAL VELOCITY DECAY MODEL

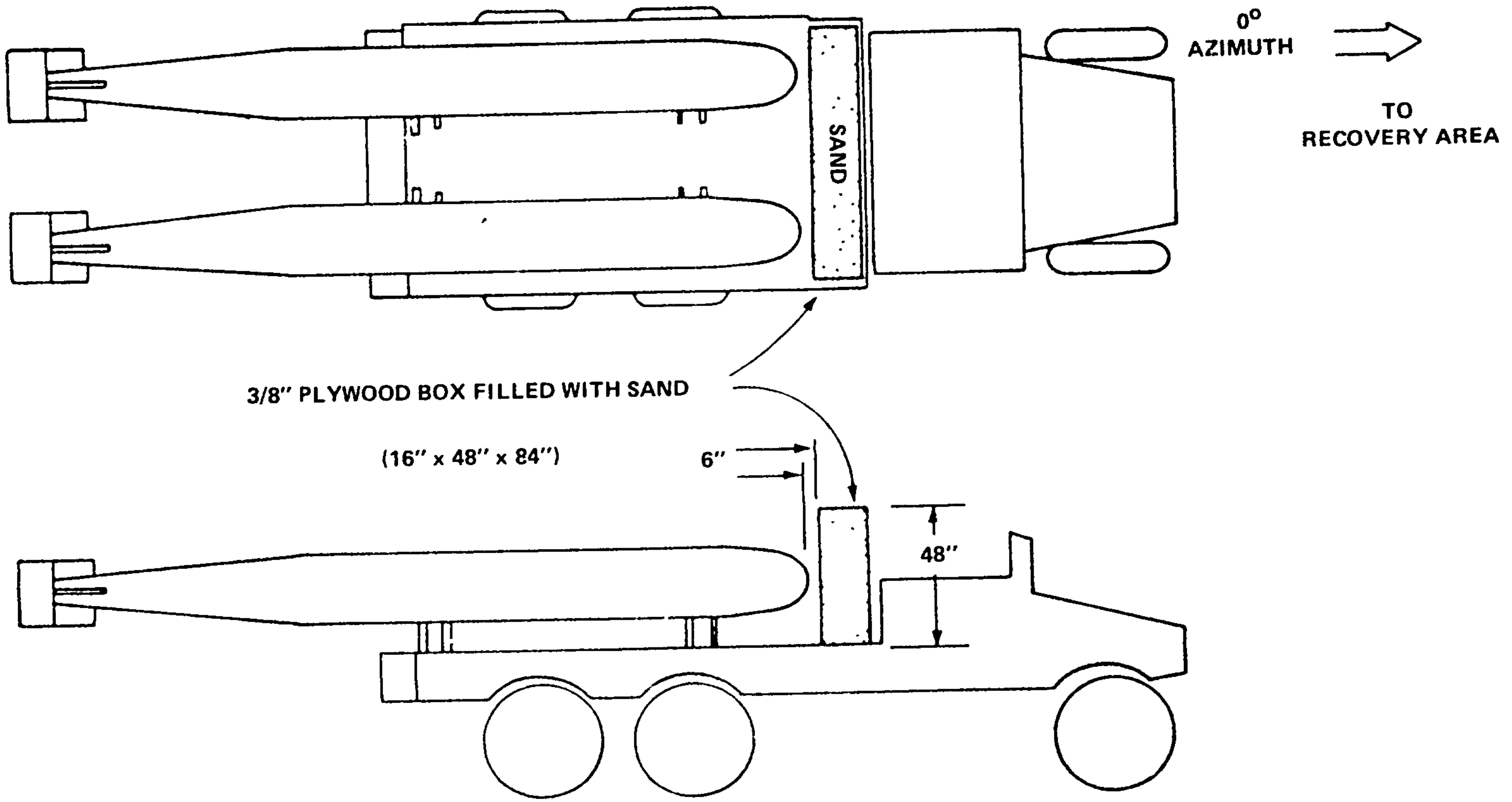

FIGURE 1 MINIMAL BLAST AND FRAGMENT SHIELD

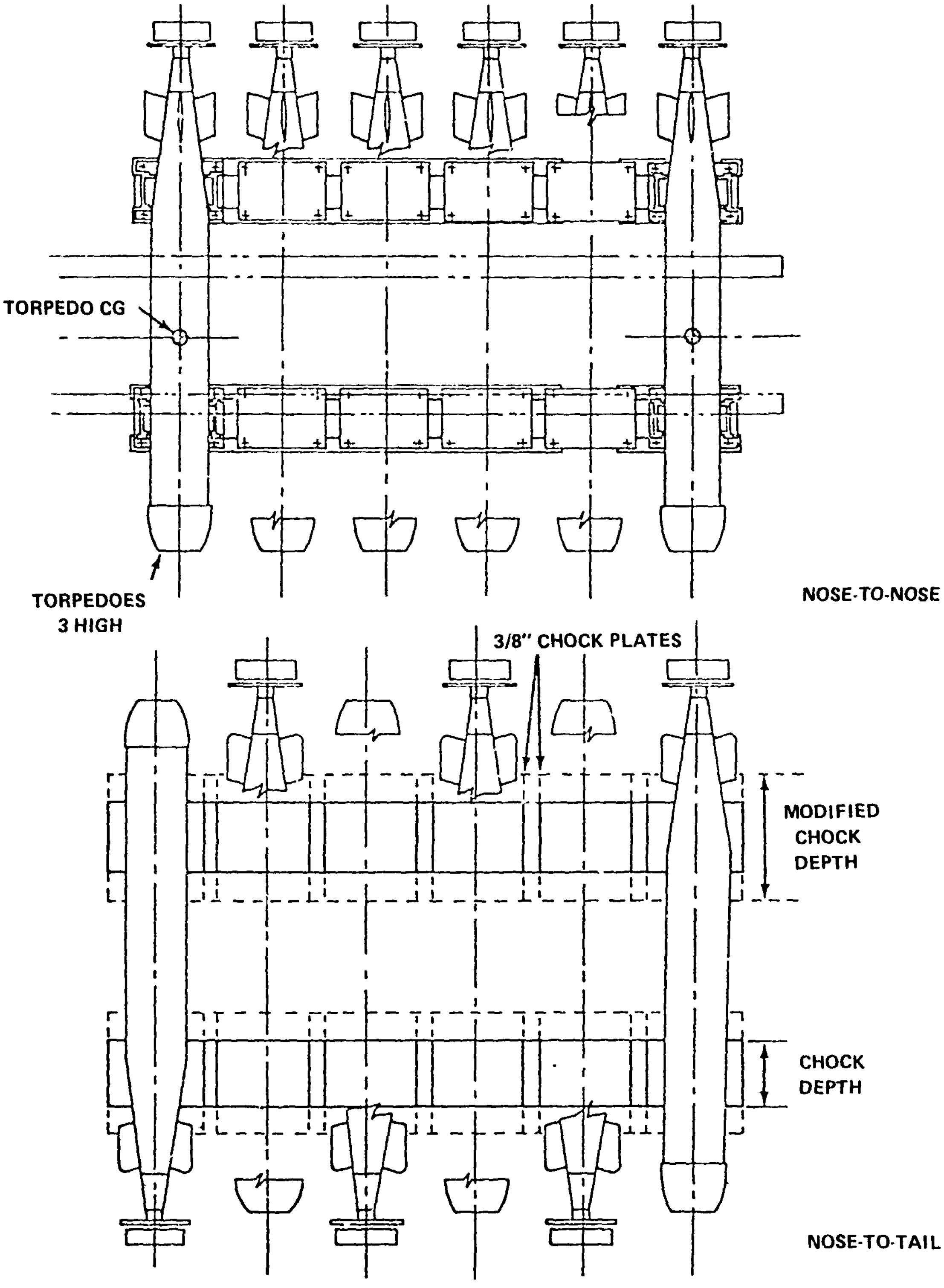

FIGURE 2 NOSE-TO-NOSE VS NOSE-TO-TAIL TORPEDO ARRANGEMENT

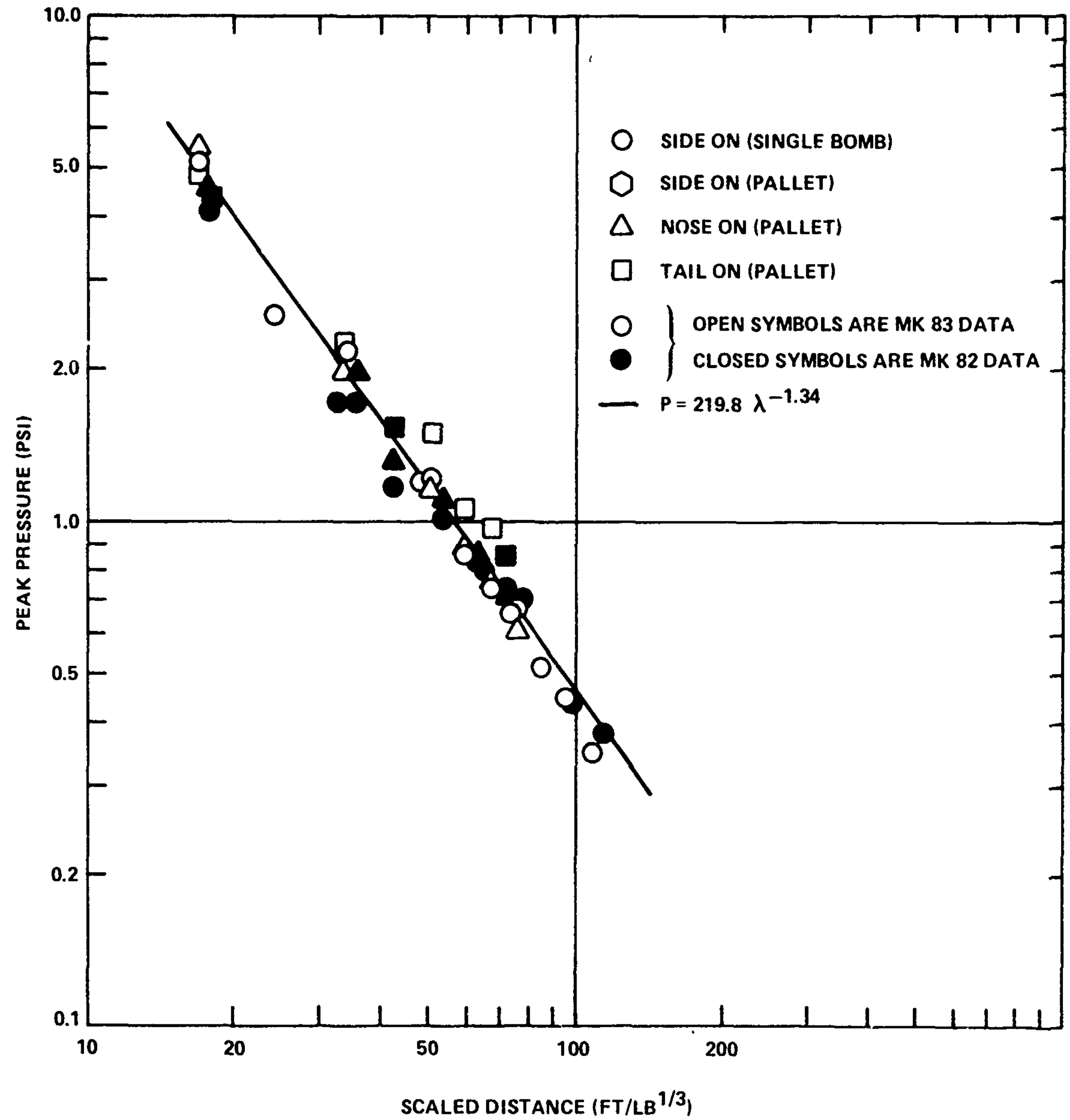

FIGURE 3 NESIP GENERATED MK 80 DATA

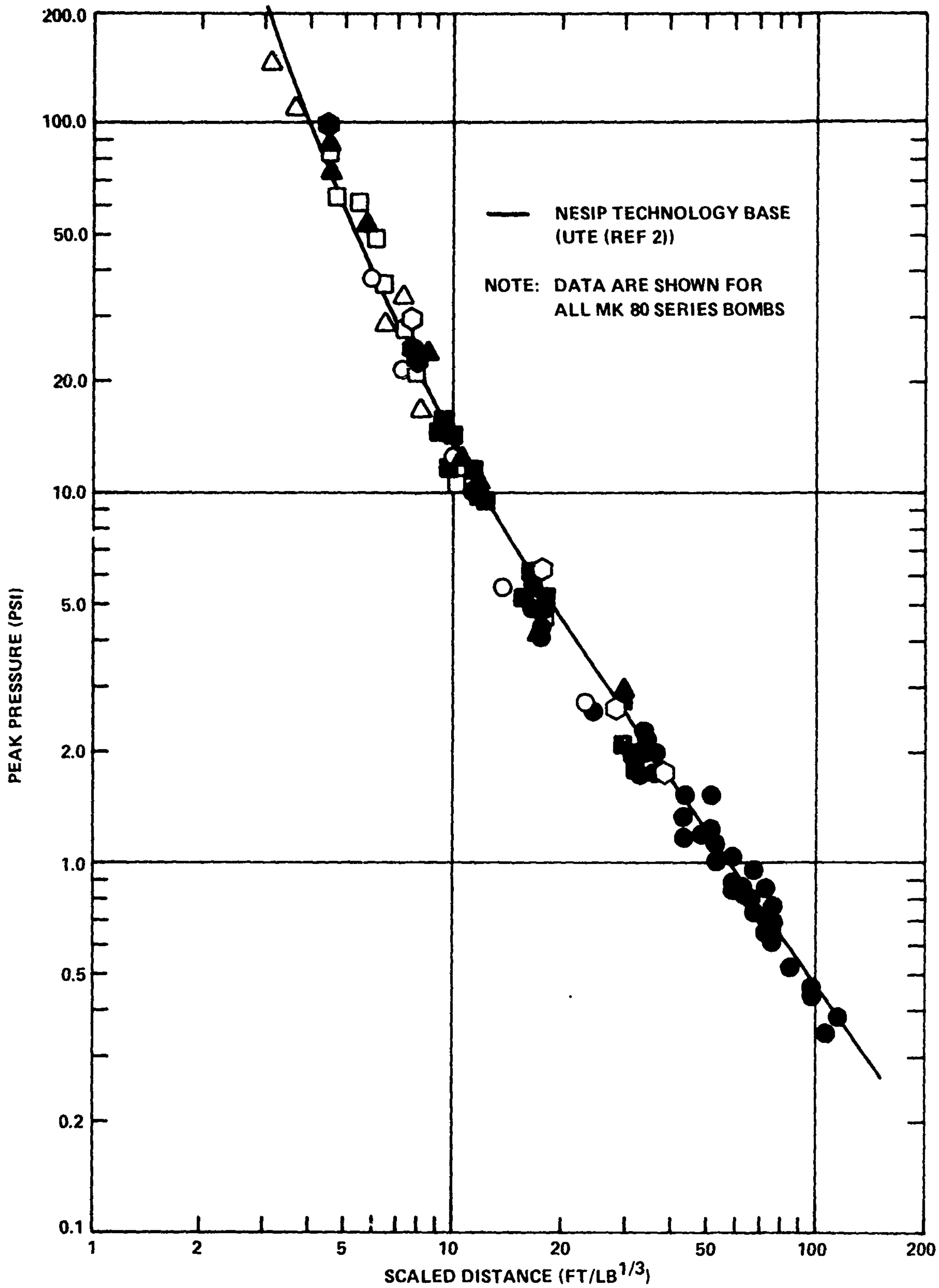

FIGURE 4 COMPILED MK 80 SERIES AIRBLAST DATA

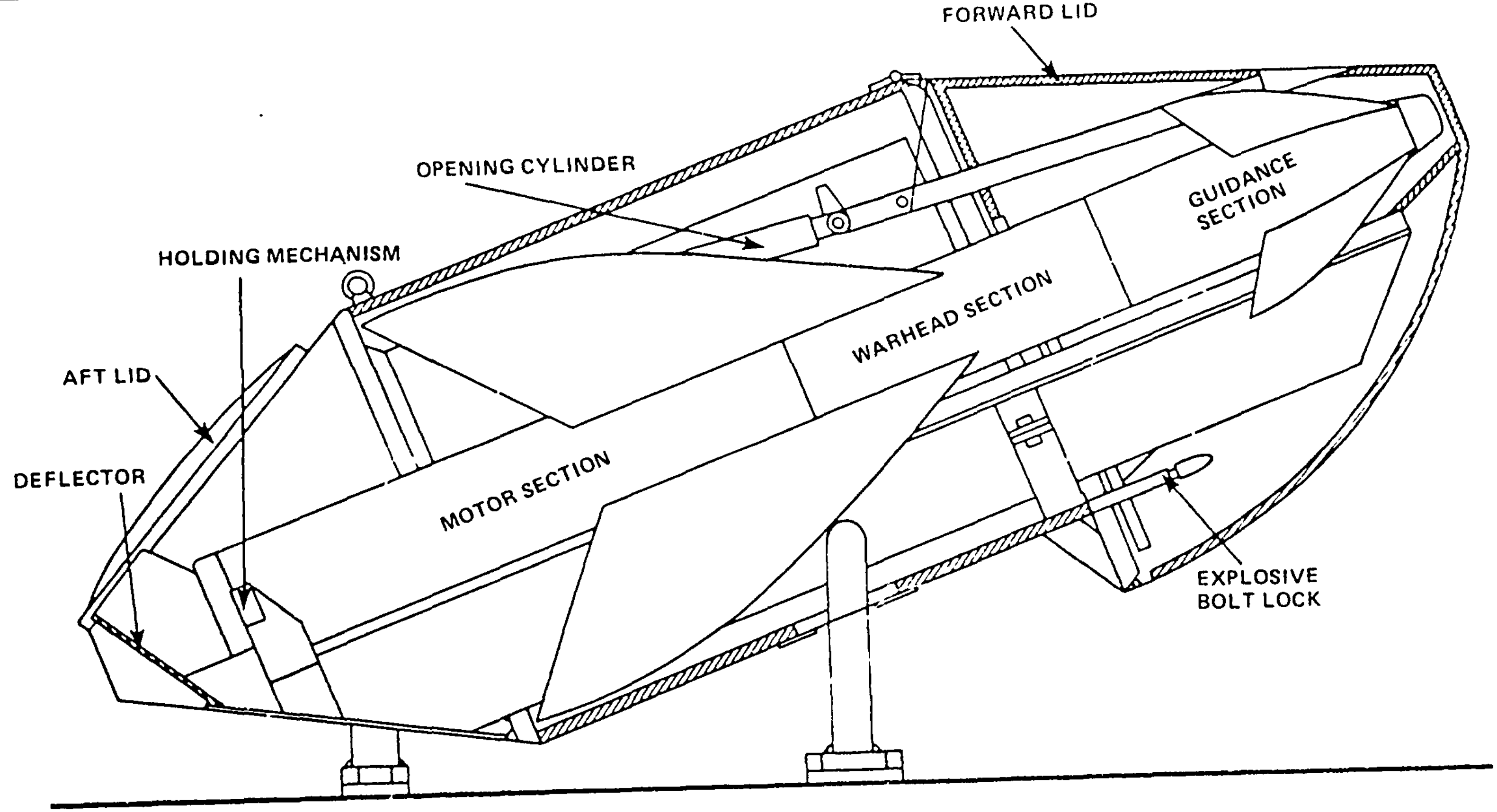

FIGURE 5 PENGUIN IN BOX LAUNCHER

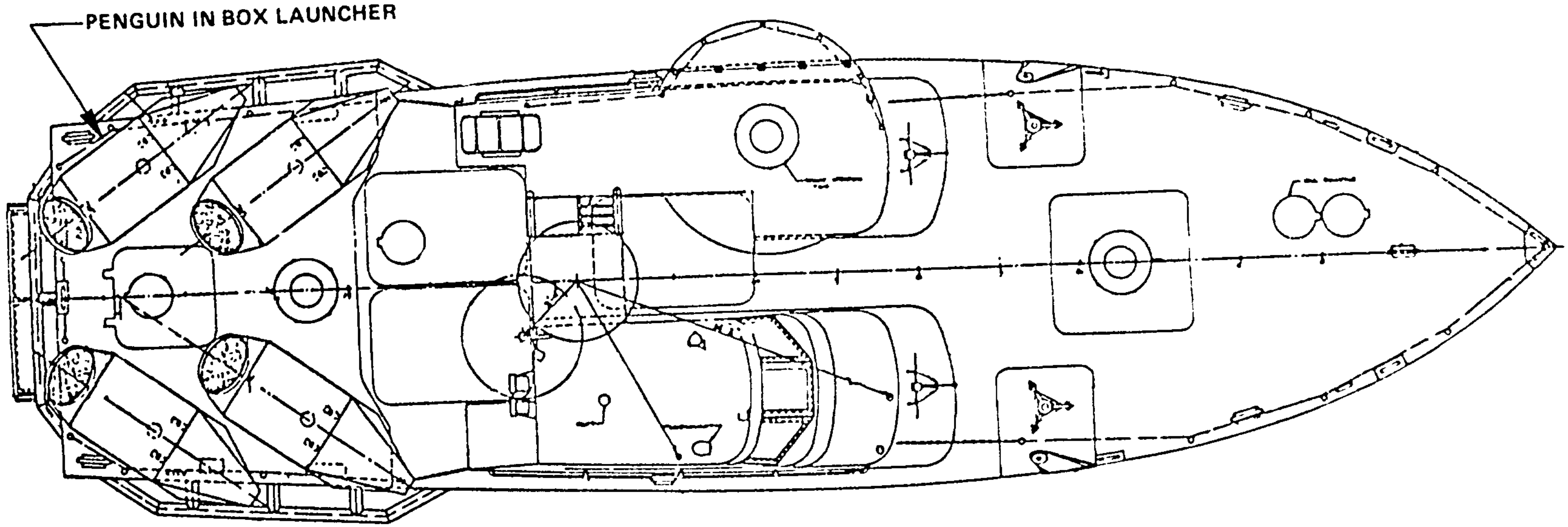

FIGURE 6 PATROL BOAT MK 3 CONFIGURATION FOR PENGUIN/BOX LAUNCHERS

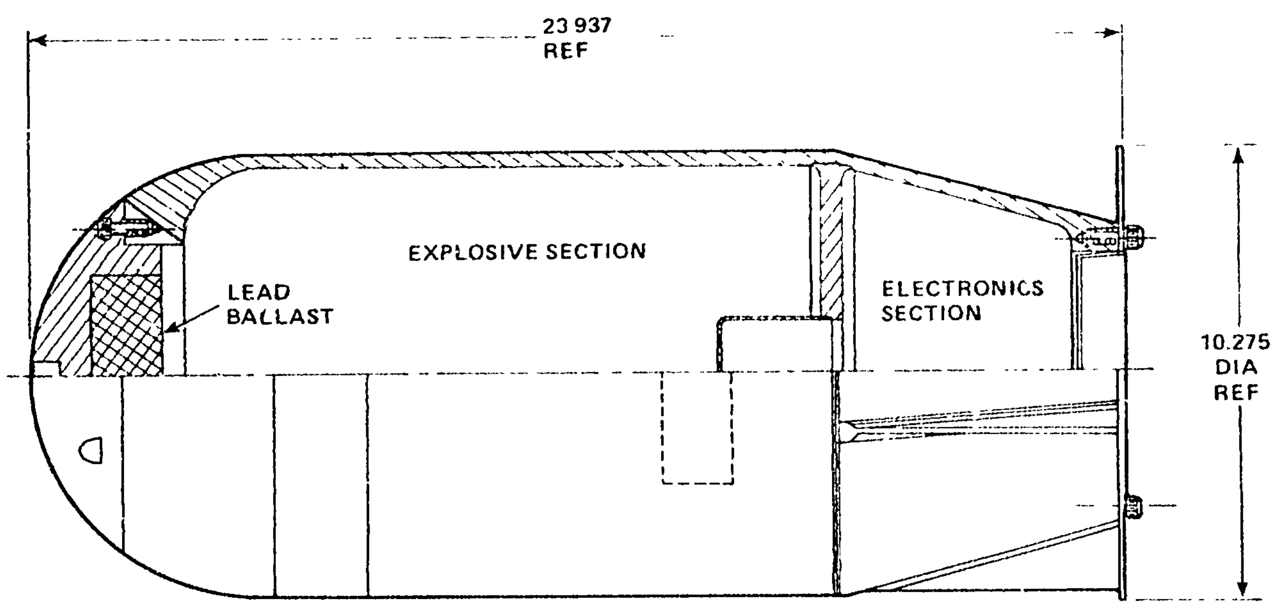

FIGURE 7 MINE NEUTRALIZATION SYSTEM BOMBLET (DESTRUCTOR MK 14 MOD 0)